CHAPTER 18

18.1 GOVERNMENT PROGRAMS

The New Zealand government's state policy for energy is to ensure the continuing availability of energy services at the lowest cost to the economy as a whole, consistent with sustainable development. Direct government funding is not available for the development or assistance of renewable energy. However, the Energy Efficiency and Conservation Authority (EECA) is funded by the government for the purpose of promoting the uptake of energy efficiency and conservation and renewable energy. With respect to renewable energy, EECA's primary function is to disseminate information on potential energy sources and their application.

18.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

The total grid-connected wind turbine capacity in New Zealand remains at just under 4 MW. The installed wind turbines include seven Enercon E40 turbines (the 3.5-MW Hau Nui wind farm), a Vestas V27 owned by the Electricity Corporation of New Zealand (ECNZ), and various small turbines owned by other parties.

New Zealand's first commercial wind farm (Hau Niu) completed its second year of operation. The predicted energy production for the 1997–1998 year was 12.6 GWh, based on an average wind speed of 9.7 m/s. The owners, the local power company, Wairarapa Electricity, recorded an actual energy production of 14.35 GWh for the year to June 1998. Availabilities of the Hau Nui turbines to date have been high, achieving an average greater than 99%.

The ECNZ V27 wind turbine in Wellington produced 1.09 GWh in the year to June 1998, with a capacity factor of 51.2%. The availability was just over 98%. The energy produced was a new record for the machine. The research and demonstration wind turbine generator has produced an average of 0.96 GWh per year for the five years to June 1998.

Construction started in October 1998 on the biggest wind farm in the Southern Hemisphere. When completed in April 1999, the Tararua Wind Farm will compromise 48 Vestas V47 660-kW turbines (total 31.7 MW) on 40-m lattice towers. The wind farm is located 10 km from the city of Palmerston North, in an area with above 10 m/s annual mean wind speed. With a net capacity factor of 50% and the predicted annual energy output of 136.7 GWh, it will be one of the most productive wind farms in the world.

Planning for the proposed ECNZ wind farm at Makara near Wellington is on hold due to the impending split of the government owned utility into three separate generators. Other power companies and developers continue to monitor and assess various potential wind farm sites around New Zealand.

In New Zealand, the majority of electricity is produced by hydro-power stations with an installed capacity of approximately 6,140 MW. The remainder of the nation's electricity is produced by fossil fuel and geothermal power stations, which together have an installed capacity of approximately 2,860 MW.

18.3 ECONOMICS

New Zealand has a deregulated wholesale electricity market in which wind power competes directly with other forms of generation without subsidies or incentives. The overall average wholesale power price for 1998 was approximately 4.5 NZ cents/kWh, with some large spot price variations occurring in the newly implemented electricity market. Extra charges are applied to the wholesale price for transmission of the electricity.

Wind power plants constructed at the best sites in New Zealand are expected to produce electricity at a cost of between 5.0 and 7.0 NZ cents/kWh, given current wind turbine prices.

18.4 MARKET DEVELOPMENT

In 1998, the New Zealand government passed legislation to enact major changes to the electricity industry. In addition to the previously mentioned split of the major generator, ECNZ, into three competing but still government-owned companies, there has been a fundamental change to the retail end of the market. Local distribution and retail companies have been forced to separate their line and energy businesses, leading to most selling their customer bases to the five or six large generators in the market. There is expected to be an appreciable reduction in the wholesale price of electricity in the short run. Consequently, retail prices are also expected to drop, spurred further by full contestability for customers.

The changes in the electricity market have had an adverse impact on proposed wind development. The expected price reductions will make wind energy even less economic and, together with the current excess generation capacity, means further wind energy development is not expected in the near future, unless a strategic or niche opportunity exists.

18.5 GOVERNMENT SPONSORED R, D&D PROGRAMS

The New Zealand government is funding wind power related research work through its contestable Public Good Science Fund (PGSF). A number of wind energy related projects were approved in the 1998 funding round and these are currently underway.

CHAPTER 19

19.1. GOVERNMENT PROGRAMS

19.1.1 Aims and Objectives

The government policy is that Norway, in a year with average rainfall, should be self-sufficient with electricity from renewable energy sources. So far this has meant mainly hydro-power. Because remaining new hydro-power projects are limited both in size and quantity, more emphasis will be placed on wind energy. So far no specific target for wind energy use has been defined.

19.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

19.2.1 Installed Wind Capacity

The first new wind turbine projects since 1993 were commissioned during 1998, increasing the total national installed capacity from 3.9 MW to 9.3 MW.

One wind farm consisting of five Wind World turbines, each rated at 750 kW, was erected at the southernmost tip of Norway, Lindesnes, by the utility company Vest-Agder Energiverk. Estimated annual production is about 12 GWh / year.

The utility company Nord-Trøndelag Elektrisitetsverk installed a 1.65-MW turbine at Hundhammerfjellet, quite close to the existing wind farm at Vikna. Estimated annual production is 4.8 GWh / year. If this unit works successfully, and economic conditions allow it, the owner is planning to extend the project by nine more units at 1.65 MW each.

An overview of the Norwegian wind turbines and the energy production, both in 1998 and accumulated, is shown in Table 19.1.

One case of a turbine blade destroyed by lightning was reported during 1998. No other serious incidents have been reported.

19.2.2 Installed Conventional Capacity

The total Norwegian electricity generating capacity is about 27,681 MW, whereof 98.9% is hydro-power. The mean energy production from hydro-power is 112.9 TWh / year.

Table 19.1 Wind Turbines and Output

WIND TURBINE PROJECTS	YEAR	NO. UNITS	TOTAL POWER (kW)	PRODUCTION 1998 (GWH)	ACCUMULATED PRODUCTION (GWH)
Frøya	1986	1	55	0.148	1.634
Frøya	1989	1	400	0.926	7.212
Vallersund	1987	1	75	0.170	2.079
Kleppe	1988	1	55	0.037	0.459
Smøla	1989	1	300	0.701	5.792
Andøya	1991	1	400	1.046	7.151
Vesterålen	1991	1	400	0.929	7.999
Vikna I & II	1991	5	2200	5.909	41.869
Hundhammarfjellet	1998	1	1650	1.461	1.461
Lindesnes	1998	5	3750	4.801	4.801
TOTAL		18	9285	16.127	80.457

19.3 MANUFACTURING INDUSTRY

19.3.1 Status

There are at present no manufacturers of complete wind turbines in Norway, due to the fact that the market for wind turbines is too small. However Kværner Energy is developing a 3-MW wind turbine, and expects to have at least two installations ready by the end of year 2000.

19.3.2 Technical Developments

Some industrial companies provide components and related services for wind turbines. During 1998, the Norwegian Research Council did grant support to the following projects related to technical wind energy development.

The company F. K. Smith has recently patented a system measuring power transmission in rotating machinery. The system was initially meant to be used for marine purposes, and the project has now been extended, in collaboration with RISØ, to be tested full-scale on a test wind turbine in Denmark

One cast iron foundry, Kristiansand Jernst Peri, has started a project to develop new and better products for large wind turbines (1.5 MW and upwards) in collaboration with the Casting Development Centre at the University of Birmingham, UK. The test samples will be analyzed with respect to stress and fatigue characteristics.

19.4 ECONOMICS

19.4.1 Electricity Prices

The Norwegian spot market price of electricity in 1997–1998 at the main grid level is shown in Figure 19.1. The average price in 1997 was 135 NOK / MWh and in 1998 116.3 NOK / MWh.
(1 NOK = 100 re = USD 0.133) This price may represent the typical buy-back price for wind-generated electricity, delivered into the transmission grid system.

In addition to the spot market price, costs covering transmission, capital costs on investments, operation and maintenance, and taxes must be included to estimate the resulting wind energy price.

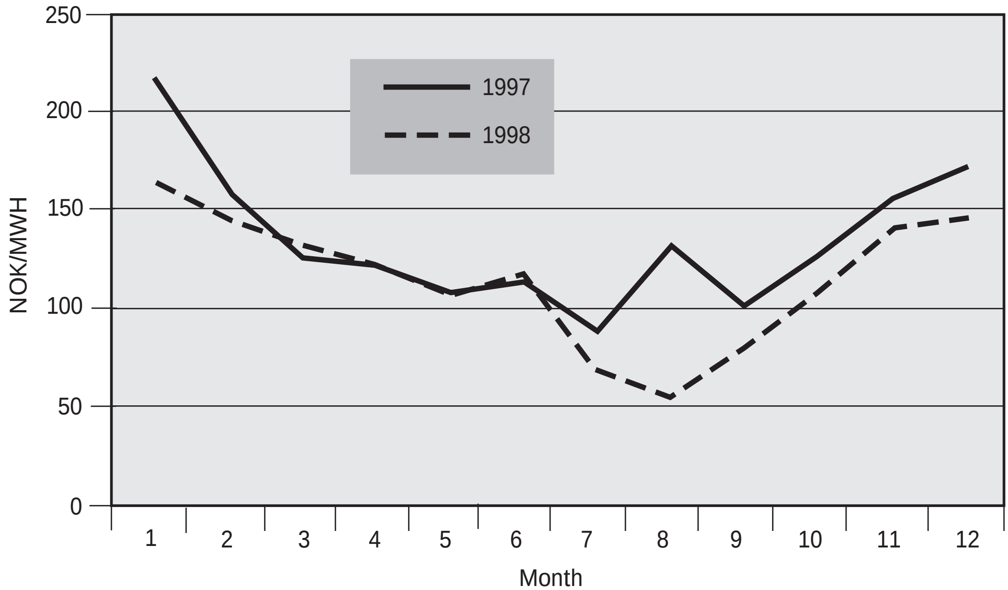


Figure 19.1 Spot Market Price of Electricity in Norway 1997 / 1998

19.4.2 Invested Capital

The cost of the Norwegian wind turbines erected in 1998 is about 47 MNOK, of which about 15% were government grants.

19.4.3 Project Costs

Estimations on production costs from sites with favorable wind conditions suggest a production cost of as low as 25-30 NOK / MWh, or 25-30 re / kWh. (1 NOK = 100 re = USD 0.133), including capital costs, operation, and maintenance. Thus, compared with the shown spot market electricity price, wind energy cannot compete on commercial terms. However, compared with the price of new hydro-power projects, some wind energy projects are almost competitive.

19.5 MARKET DEVELOPMENT

In order to enhance the introduction of wind energy in Norway, several measures have been introduced in 1998, effective January 1, 1999. One is an exemption from the investment tax for wind turbines and related equipment. Another recently introduced measure is an energy production support, equaling half of the general electricity levy. Furthermore, there will be a need for financial support, which very likely will be given to projects based on a competition between them. One common criteria related to these measures is that each unit should be at least 500 kW, and the total project installation should be at least 1.5 MW.

Both wind turbine installations realized during 1998 were granted support of about 15% of the investment cost.

Three project developers applied for licenses to install new wind power plants in 1998, with a total capacity of 9.8 MW. In addition, preliminary plans for nine large wind farms have been presented, as the basis for identifying the entire consequences of the projects. The total capacity of these plants is about 520 MW, with an estimated annual energy production of about 1,560 GWh / year. The estimated need for financial support to establish these plants is roughly 625 million NOK. It is not likely that all the preliminary plans will be realized, due to various reasons.

19.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

The following projects during 1998 were financed by The Norwegian Research Council and / or by the Norwegian Water Resources and Energy Directorate, NVE.

1. The companies Triad AS and Contec Design have developed a patented system for measurement of wind speeds with very high resolution both in space and time. The system range is from above ground up to altitudes of approximately 400 meters. The system is based on the interaction between radio transmission equipment and an acoustic system of 200 loudspeakers in a grid system.
2. The company Vector is running a project using numerical flow simulations based on existing wind measurements, to form a rough wind atlas, as a basis for deciding where to locate wind farms.
3. SINTEF Energy Research has investigated the feasibility of establishing a wind energy center in Norway. The study concludes that there is a marked need for such a center to serve Norwegian utilities and industry. A decision on whether or not to establish the center is expected during 1999.
4. Within the framework of IEC, SINTEF Energy Research is heading the development of a new standard on power quality requirements for grid-connected wind turbines. The standard is now present as a committee draft for comments.

5. The research on wind energy at the Institute for Energy Technology in 1998 has been focused on meso-scale modeling of atmospheric flow and optimization tools for wind turbine rotors. Both tasks have been carried out as Ph.D studies.

CHAPTER 20

20.1 GOVERNMENT PROGRAMS

20.1.1 Aim and Objectives

Spain is a country with excellent wind resources and a well-developed technology in the wind energy field. This technology has come from the very active participation of Spanish industry in research and development programs during the past years.

At the present time, wind energy has a very promising future in Spain. The total power installed at the end of 1998 was 833.7 MW and more than 2,500 wind turbines were in operation. The estimate for the next year is that over 650 MW will be installed in new wind farms. This will allow reaching the milestone of 1,500 MW of wind power operating in Spain by the end of the millennium.

The main participants in the structure of the Spanish electric supply system are coal-thermo plants (47%,) hydroelectric plants (36%) and nuclear plants (16%).

The targets relating to the use of renewable energy sources are described in the Energy Saving and Efficiency Plan (P.A.E.E.)

Figure 20.1 Due to excellent resources and a well-developed technology, wind energy has an excellent future in Spain.

contained in the Spanish National Energy Plan. This Plan foresees an increase of 25% in the use of renewable energy for the year 2000 compared to 1990.

The Spanish government is supporting the use of renewable energies and its policy is in agreement with the general objectives defined in the European Union: economic growth, creation of employment, maximum self-sufficiency, and raising the quality of life of inhabitants through improved environmental conditions. The new Royal Law 2818/1998-23 December 1998, about the Electrical Special Regime for renewable energy plants connected to the grid, has the target of “the contribution of the renewable energies to the Spanish energetic demand, will be at least 12% for the year 2010.”

The wind goal of 168 MW by the year 2000 foreseen in the P.A.E.E. has been widely surpassed reaching and exceeding such amount in the year 1996.

20.1.2 Strategy

The strategy followed for the development of wind energy in Spain has been implemented in several steps. At the beginning and during the period 1980 to 1985, the program focused on assessing national resources and also developing the national technology. As a result of the programs (national, and utilities program), two of the present leaders of the Spanish industry, Made and Ecotécnia emerged with wind turbines developed in the range of the 20-30 kW. During the period 1985-90, the continuation of the resource assessment at the regional level and the demonstration program launched by the public organization IDAE (Institute for Diversification and Saving of Energy) for installation of several small wind farms allowed the consolidation of the newly created industry.

Table 20.1 Estimated Power by Region

REGION	ESTIMATED POWER (MW)	YEAR
Galicia	2800	2007
Aragon	1000 2500	2007 2012
Navarra	220 650	2000 2010
Andalucia	500	2000
Islas Canarias	150 300	1998 2002
Cataluña	300 1000	2005 2010
Castilla-Leon	250 1000	2000 2005
Murcia	50	2000
Pais Vasco	500	2005

At that time, CIEMAT, the main public research center in the field of energy research in Spain, started activities in wind energy through the development of the AWEC-60 project (a 60 m diameter, 1,200-kW wind turbine) inside the R&D program of the DG XII of the European Union.

Finally, in the period 1990-1995, the definitive impulse (once the Spanish industry was ready to fulfill the requirements of the future market) was the publication of Royal Law of 2366/1994. This law guarantees the electricity price to be paid by the utilities to the wind power plants. This was the beginning of a new era of wind energy in the country.

20.1.3 Targets

The majority of the autonomies have regional wind energy programs that add to a total target of more than 8,000 MW to be installed in the next decade. Table 20.1 Estimated Power by Region, shows these estimates.

20.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

20.2.1 Installed Capacity

In 1998, another 407 MW of wind energy were installed, and total capacity at the end of December 1998 was 833.7 MW. Installed capacity doubled from December 1997 (427 MW) to December 1998. (See Figure 20.2)

The predictions for the year 1999 foresee the installation of around 650 MW in new wind farms. At the end of 1999, the total power installed will reach 1,500 MW. Galicia and Navarra are the autonomous communities with the most activity during 1998, with 137.6 MW and 129 MW installed in 1998. The new wind farms are large and medium-sized, mainly owned by consortiums formed by utilities, regional institutions involved in local development, private investors, and, in some cases, the manufacturers. Private individuals are not taking an important role in the development of wind energy in

Table 20.2 Growth of Wind Generation Capacity

YEAR	POWER INSTALLED (MW)	ACCUMULATED POWER (MW)	ANNUAL GROWTH RATE
1994	23	73	46%
1995	46	119	63%
1996	95	214	80%
1997	213	427	100%
1998	407	834	95%

Spain. Table 20.3 lists the new wind farms installed in 1998.

The wind turbines installed are between 300 to 700 kW of rated power. The majority of the new capacity installed in 1998 was wind turbines manufactured in Spain (Gamesa Eólica, Made, Ecotécnia, Desa and Bazan-Bonus). Table 20.4 lists the 32 new wind farms connected to the grid during the year.

20.2.2 Operational Experience

The production data of wind power plants for 1996 (the most recent year for which we have data) is summarized in Table 20.5.

From the analysis of the production data of the wind turbines operating in Spain in 1996, the average capacity factor is 0.29, equivalent to 2584 hours per year at full load. Table 20.6 shows the result of the analysis.

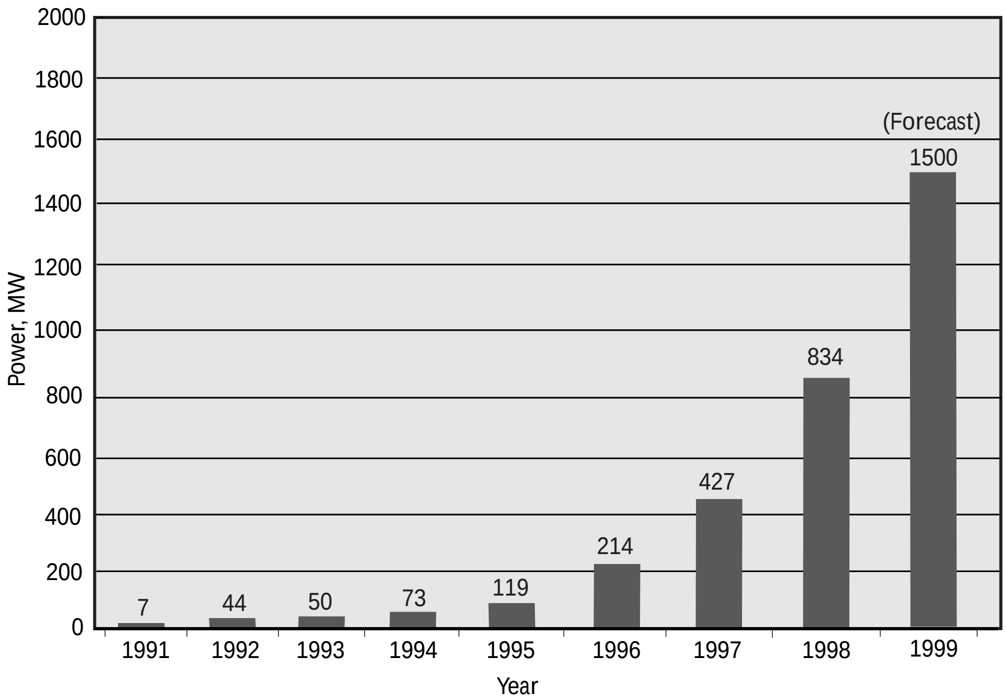


Figure 20.2 Wind Installations in Spain

Table 20.3 Total Installed Capacity and New Installations During 1998

AUTONOMOUS COMMUNITY	NO. OF PROJECTS IN 1998	POWER INSTALLED IN 1998 (kW)	TOTAL POWER (MW)
Andalucía	1	30,000	115
Aragón	5	52,340	128
Canarias	7	20,635	79
Castilla y León	2	15,450	16
Cataluña	2	15,100	20
Galicia	8	137,610	232
Murcia	1	5,940	6
Navarra	6	129,000	237
TOTAL	32	406,075	834

Table 20.4 WECS Installed in Spain During 1998

PROJECT	MANUFACTURER	NO. OF MACHINES	TOTAL POWER (kW)
Tahivilla	D.E.S.A.	100	30,000
Valdecuadros	TIAM-NEG-Micon	1	600
Muel	TIAM-NEG-Micon	27	16,200
Coriscada I	Gamesa-Eolica	20	12,000
Remolinos*	Gamesa-Eolica	3	1.980
La Plana III*	Gamesa-Eolica	10	6,500
Planas de Pola (phase 1)	Gamesa-Eolica	41	27,060
Aguimes	A.C.S.A.	2	450
La Vereda	A.C.S.A.	1	225
Bahia de Formas II	Enercon	4	2,000
Granadilla II–ITER	Enercon	11	5,500
Centro Ciea–ITC	Enercon	2	460
Ol Vega	Made	45	14,850
Faro de Fuencaliente	Made	5	1,500
Finca de Mogan	Made	35	10,500
Paramo de la Lora	Made	1	600
El Pradell (phase II)	Ecotecnia	66	14,850
La Llacuna	Enercon	1	250
Coriscada (phase II)	Gamesa-Eolica	20	12,000
Zas	D.E.S.A.S.	80	24,000
Barbanza	Made	1	660
Muras I	Gamesa-Eolica	37	24,420
Vicedo	Bazan-Bonus	41	24,600
A Capelada*	Made	45	14,850
Bustelo	Made	76	25,080
Sierra de Ascoy	Gamesa-Eolica	9	5,940
Serralta	Ecotecnia	25	15,000
San Gregorio	Ecotecnia	25	15,000
Echague	Gamesa-Eolica	35	23,100
Alaitz	Gamesa-Eolica	40	26,400
Izco	Gamesa-Eolica	50	33,000
Aibar	Gamesa-Eolica	25	16,500
TOTAL		884	406,075

*second phase of the project

Table 20.5 Production Data of Wind Power Plants

Power Installed 12/31/96	216 MW
Energy Produced	370 GWh
Average Capacity Factor	0.29
Specific Annual Energy	1074 kWh/m^2
Equivalent Full Load Hours	2584

Table 20.6 Wind Turbine Capacity Factors for 1996

Capacity Factor, %	% of the Wind Turbines
<20	5.8
20–30	50.0
30–40	39.0
>40	7.2

The average value of specific energy production (ratio between annual energy and rotor area of the wind turbine) for 1996 was 1074 kWh / m^2. (See Table 20.5 for detailed distribution.)

Table 20.8 shows the comparison with the previous years.

There was an increase in the average capacity factor and in the specific energy for the year 1996 over the years 1994 and 1995.

Table 20.7 Wind Turbine Energy Production for 1996

Specific Energy (kWh/m^2)	% of the Wind Turbines
<500	2
500–1000	35
1000–1500	52
>1500	10

20.3 ECONOMICS

20.3.1 Electricity Prices

In December 1994, the Spanish government introduced Royal Law 2366, which regulates the price to be paid to self-generators. This covers cogeneration, minihydro, photovoltaic, and wind power plants. This regulation brings the existing regulations together in a single text and develops the basic criteria for technical and economic relations between owners and utilities. The regulation applies to wind power plants up to 100 MW.

The newer law of November 27, 1997 (D. 54 / 1997) liberalized the electrical power market, opening the market to private enterprises. The liberalization policy is compatible with the target objectives such as energy efficiency, consumption reduction, and environmental protection. Measures to encourage the exploitation of renewable energy sources are incorporated into the Law.

Table 20.8 Wind Turbine Production Data

	1994	1995	1996
Power Installed by December 31	70 MW	125 MW	221 MW
Average Capacity Factor	0.26	0.28	0.29
Specific Annual Energy	981 kWh/m^2	1040 kWh/m^2	1074 kWh/m^2
Equivalent Hours at Full Load	2277	2453	2584

The new Royal Law 2818/1998-23 December 1998, about the Electrical Special Regime for renewable energy plants connected to the grid, fixed the conditions of the plants to be included in this special regime. This law is a new step in the strategy for promoting the use of renewable energies, with the specific target that “the contribution of the renewable energies to the Spanish energetic demand, will be at least 12% for the year 2010.” All the installations using renewable energies as a primary source, with an installed power less than or equal to 50 MW could be included in that regime. The regime gives two choices to the producers. One is a fixed price for the kWh generated, and the second option is a variable price, calculated from the average price of the market-pool, plus a bonus per kWh produced. The fixed price and the bonus will be up-dated every year by the Spanish Ministry of Energy and Industry according with the annual variation of the market price. The values for 1999 are presented in the following table.

It is important to remark on the excellent conditions for the small solar plants—around 0.4 Euros/kWh. That is about four times the price per kWh charged to the consumer. The average sale price of the electricity to the consumers in 1998 was 13.19 Pts/kWh.

20.4 INDUSTRY

All this important activity in the wind energy field has stimulated the development of the Spanish wind industry. This industry includes not only the manufacture of complete wind turbines, but also the manufacture of components for the wind industry: blades, generators, gear boxes, towers, wind sensors, etc. Also the service sector (installation, maintenance, engineering) grew in the last year.

Six companies are leading the national Spanish industry: Ecotecnia, Made, Bazan-Bonus, Gamesa Eólica, Desa, and Taim-Neg Micon.

Ecotecnia started activities in wind technology development in 1981, meaning it now has more than eighteen years of experience in that field. During 1998, Ecotecnia installed 116 wind turbines of the model 28/225 of 225 kW and ECO/44 of 600 kW. Both designs are three-bladed, stall-controlled wind turbines, incorporating a very advanced design in the drive train.

Table 20.9 Total Installed Capacity and New Installations During 1998

RENEWABLE SOURCE	BONUS ADDED TO THE BASE PRICE IN 1998	FIXED PRICE (PST/kWh)	FIXED PRICE EURO/kWh)
Small Hydro	5.45	11.20	0.067
Solar Plants* (< 5 kW)	60.00	66.00	0.397
Solar Plants* (> 5 kW)	30.00	36.00	0.216
Wind Plants	**5.26**	**11.02**	**0.066**
Geothermal	5.45	11.20	0.067
Wave	5.45	11.20	0.067
Tide	5.45	11.20	0.067
Primary Biomass**	5.07	10.83	0.065
Secondary Biomass**	4.70	10.46	0.063

Euro = 166.4 Pts

* Solar plants for electricity production: PV plants and solar thermal power plants

** Primary biomass: agricultural crops; secondary biomass: agricultural and forest residues

Table 20.10 Manufacturers of Wind Turbines Installed in 1998

MANUFACTURER	NO. OF MACHINES	TOTAL POWER (kW)	NO. OF PROJECTS
Gamesa-Eolica	290	188,900	11
D.E.S.A.	180	54,000	2
Made	178	68,040	7
Ecotecnia	116	44,850	3
Bazan–Bonus	41	24,600	1
TAIM-NEG-Micon	28	16,800	2
Enercon	18	8,210	4
ACSA-Vestas	3	675	2
TOTAL	884	406,075	32

Made is another of the pioneer companies in Spain that has developed ten different models of wind turbines since 1982. At the present time, Made is concentrating their commercial effort on the model MADE AE-30 (330 kW) and MADE AE-41 (600 kW). During 1998, Made installed 178 wind turbines, making a total capacity of 68 MW

One new prototype (pitch control regulated of 500 kW), the AE-41, is in the testing phase at the Monte Ahumada Wind Farm, in the Tarifa area. Another prototype undergoing tests is a 660-kW, MADE AE-46 that is specially designed for low wind conditions.

Gamesa Eólica is manufacturing wind turbines of 600 kW, the G-42 using Vestas Technology. The majority of the components are already manufactured in Spain (including blades). During 1998, Gamesa installed 290 units for a total capacity of 189 MW.

Desa manufactures wind turbines of 300 kW and is developing a new wind turbine in the range of 600-700 kW.

Bazan-Bonus manufactures models of 600 kW, 1 MW and 1.2 MW of Bonus in a factory located in El Ferrol (La Coruña). During 1998, the company produced 41 units of the MK IV-600 kW model, and expects production of 80 units in 1999.

Also there are other Spanish manufacturers active in the wind energy industry using foreign technology (Taim-Nordtank, Acsa-Vestas) that will increase the capacity of the Spanish industry to supply the domestic and international market. In particular Spanish manufacturers are participating in the planning of projects in North Africa (Tunisia, Morocco, Egypt, and so forth). They are also increasing their marketing activities in other countries (India, China, and South American countries).

In the sector of small wind turbines, the company Bornay is the leader, with more than 150 units installed during 1998, not only in Spain but also in other European countries (Germany, Portugal, Italy, Greece) and in South America (Venezuela, Dominican Rep., and so forth). Bornay is manufacturing eight models from 60 W to 12 kW.

20.5 RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

The main R&D organization in the field of wind energy in Spain is CIEMAT, a public center for research in the technological and environmental aspects of energy production. Within CIEMAT, the Department of Renewable Energies (DER) is active in several projects including resource evaluation, prediction models, blade development and testing, and wind turbine testing (MEASNET network).

A new project has been launched, devoted to the development of stand-alone systems, with a broad field of activity, from the development of the components (small wind turbines, flywheel storage systems, control management units, etc.) to the testing of the whole system, in a new test center for isolated systems located in the CEDER plant in Soria.

Other research centers are also very active, as for example ITER and ITC in the Canary Islands, both centers involved in R&D projects in desalination of sea water using wind energy plants.

As a consequence of the increasing activities, the number of University Departments working in projects is rapidly increasing. In particular the Politechnical University of Madrid continues the work studying wakes in wind turbines, electrical systems, and blade technology. The University of Navarra is actively working on lightning in wind farms. Vigo University is developing a simplified methodology for flicker analysis and voltage and frequency variations in wind farms. The University of Las Palmas (Canary Islands) works on wind farms' impact on grid stability. They are also working on desalination plants powered by wind energy systems.

Figure 20.3 Several of Spain's windfarms are located in mountainous areas.

The majority of the R&D activities in wind energy in Spain are developed under the umbrella of the European R&D programs. The main European projects that Spain participates in are listed in Table 20.11.

At the present time, the Spanish manufacturers are starting to develop large wind turbines. However, the attitude about large wind turbines is not as enthusiastic as in other European countries, mainly due to the particular Spanish topography. In Spain, the windy areas are located mainly in mountainous regions, with difficult access that makes the transport and erection of large machinery expensive. Thus, the use of large turbines in mountainous areas is not as advantageous as when they are located off-shore or on flat terrain.

Table 20.11 European Wind Projects with Spanish Participation

PROGRAM	COORDINATOR	SPANISH PARTICIPANTS	PROJECT TITLE
JOULE	CRES (GR)	CIEMAT ECOTECNIA	Investigation of design aspects and design options for wind turbines operating in complex terrain environments (COMTER.ID)
JOULE	CRES (GR)	CIEMAT ECOTECNIA	Adaptation of existing wind turbines for operation on high wind speed complex terrain sites. (ADAPTURB)
JOULE	EUREC AGENCY	CIEMAT	European wind turbine standards II (EWTS-II)
JOULE	Univ. of Madrid (SP)	Univ. of Madrid CIEMAT	Smart technologies applied to wind turbine blades (SMART-BLADES)
JOULE	ITC-CIEA (SP)	ITC-CIEA CIEMAT Univ. Las Palmas	Seawater desalination plants connected to an autonomous wind energy system (SDAWES)
JOULE	WIP(D)	ITER	Modular desalination systems for wind energy
THERMIE	OME(FR)	CIEMAT ENDESA	Integration of renewable energies in the southern Mediterranean countries
THERMIE	CINAR(GR)	CIEMAT C.A. MURCIA	Addressing social and institutional barriers to wind energy installations
APAS	LAMDA (GR)	CIEMAT	Utilization of wind, solar and biomass resources in Mediterranean rural regions
APAS	ITER (SP)	ITER CIEMAT Univ. Las Palmas	Towards the large scale development of decentralized water desalination (Prodesal - Pro Desalination)

CHAPTER 21

21.1 GOVERNMENT PROGRAMS

21.1.1 Aims and Objectives

The objective of Sweden's energy policy is to secure the long-term and short-term supply of energy on internationally competitive terms, and to promote economic and social development based on environmental sustainability. The policy specifies that the national energy supply is to be secured by an energy system based as far as possible on sustainable, preferably indigenous and renewable, resources and on energy efficiency. Sweden's energy policy approach places considerable emphasis on economic and environmental objectives.

On February 4, 1997 an inter-party Energy Policy Agreement between the Social Democrats, the Centre Party, and the Left Party was reached. One reactor was to be closed down before July, 1 1998 (Barsebäck I), and the second reactor (Barsebäck II) before July 1, 2001. A new, long-term transformation program to develop an ecologically sustainable energy supply system has been decided. The resolution to close down the first reactor has however been inhibited. So it is now uncertain when it will be shut down.

The authority responsible for transforming the Swedish energy supply system into an ecologically sustainable system is the Swedish National Energy Administration, which was formed January 1, 1998. The finance program has a total budget of MSEK 1300 for 1998.

21.1.2 Government R,D&D

Sweden has a good wind energy resource and was one of the first countries to embark on a wind energy program in 1975. The government is supporting the development and installation of wind turbines in two programs managed by the Swedish National Energy Administration (Statens energimyndighet).

1. A fully financed research program with a three-year budget of SEK 46.8 million for 1998-2001. (The program is described below),
2. A development and demonstration program for wind systems, with a maximum of 50% support.

The utilities are engaged in studies, demonstration, and evaluation projects. Since 1994, the research and development activities of these utilities have been coordinated in a jointly owned company, Elforsk AB, which initiates projects and finds sponsors in the field of power generation. In addition to the activities of Elforsk AB, the largest utility, Vattenfall AB, has a substantial wind energy development program of its own.

21.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

21.2.1 The Electricity Market—Regulations for Small-Scale Production

On January 1, 1996 a new Electricity Act came onto force, replacing the old one from 1902. The aim of the new act is to introduce competition in the electricity market thus creating the conditions for efficient pricing and a more open market in electricity. Competition in the electricity market makes it possible for buyers to choose freely among different vendors. Until now, one obstacle for buyers in the free market has been the cost of the required meter for measuring hourly electrical use. However, since November 1, 1999, the requirement for an electricity meter will probably be eliminated and be replaced by "metering" with statistical profiles for consumption.

With the aim of protecting the small power producers during the transition to a new competitive electricity market, a delivery concession was introduced in the Act, for a five-year period, from 1996 to 2000. Holders of a delivery concession are responsible for purchasing electricity from each power generation plant (<1500 kW) located within their region.

The price is set equal to the household tariff, minus reasonable costs for administration and profit. The wind turbine owner also gets an income from the net owner related to the value of the decreased net losses. The deregulated market also allows wind turbine owners to sell their electricity to any customer. This creates a "wind electricity market."

On November 1, 1998 a government committee for evaluating the system of supply concessions started its work of evaluating the rules on the deregulated electricity market. The results will be presented on November 1, 1999.
The regulations after the year 2000 for small-scale electricity producers are uncertain until then.

21.2.2 Installed Wind Energy Capacity

The increase in annual power generation from wind turbines and the installed capacity in Sweden by December 31 each year is shown in Figures 21.1 and 21.2.

The total installed wind power capacity in Sweden was 174 MW on December 31, 1998 —an increase of 52 MW since December 31, 1997 (+43%). In 1998, the number of wind turbines has increased by 87 to 421 turbines (+26%). In 1998, wind power generation was 300 GWh—an increase of 46% since 1997 (205 GWh). The total installed electricity capacity and generation in Sweden is shown in Table 21.1.

21.3 MANUFACTURING INDUSTRY

21.3.1 Status / Numbers / Sales of Manufacturers

Two manufacturers have developed large wind turbines in Sweden: Kvaerner Turbin AB and Nordic Windpower AB.

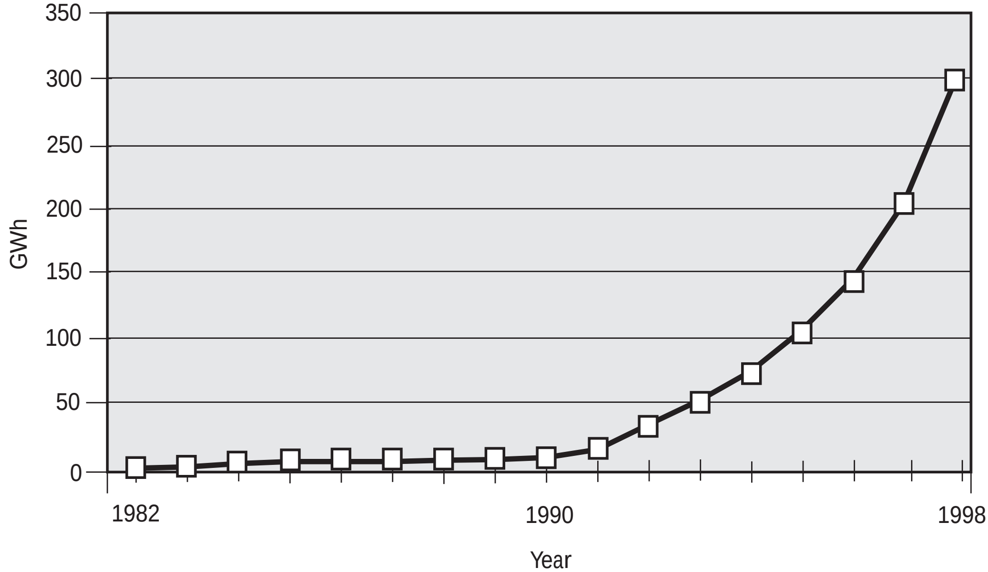


Figure 21.1 Wind Power Generation

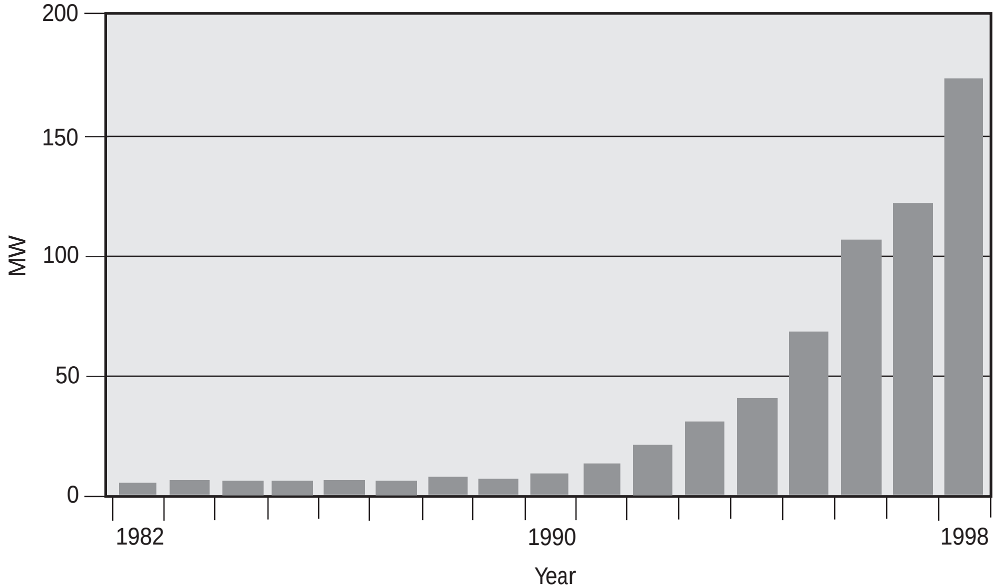


Figure 21.2 Wind Power Capacity

Kvaerner Turbin AB has developed and sold Näsudden I (2000 kW) and Näsudden II (3000 kW). Vattenfall AB is the purchaser of both turbines. Kvaerner has also been part of the OPTI OWEC project for offshore wind turbines in Europe within the THERMIE Programme.

Nordic Windpower AB has developed and sold Nordic 1000 (1000 kW at Näsudden, Gotland). Vattenfall AB is the purchaser of the turbine.

21.4 ECONOMICS

21.4.1 Electricity Prices

The prices in the market for high-voltage electricity paid by certain customers, industrial plants, and distributors may be close to the bulk power price. In the market for low-voltage electricity, the distribution costs are considerably higher. The price of bulk power as a proportion of the price paid by the end customer is consequently relatively low at just under

Table 21.1 Total Installed Electricity Capacity and Generation in Sweden–1998.

GENERATOR TYPE	1998 MW	1998 TWh
HYDRO POWER	16,246	73.2
NUCLEAR POWER	10,056	70.2
THERMAL POWER PRODUCTION (CHP, cold condensing)	4,805	9.7
WIND POWER	174	0.3
NET IMPORT		-10.4
TOTAL	31,281	143.0

one-third of the price, excluding taxes, payable by a household without electric heating (Table 21.2). The prices charged to various customer categories are determined by tariff systems, which are made up of a mixture of variable and fixed charges.

21.4.2 Turbine / Project / Generation Costs

At good sites, today's commercial wind power plants can produce electricity at a cost of SEK 0.26–0.32 / kWh (without state subsidy) depending on the site. In Sweden, support is generally required for wind power to be economically viable.

The wind power plants that are erected today have a capacity between 250 and 1500 kW with a majority of 600 kW wind energy conversion systems.

21.4.3 Value of Generated Power

The price paid for electricity produced by wind turbines during 1998 was around 0.25 SEK / kWh (including net value payment). The value is increased by an "environmental bonus," at SEK 0.152 / kWh. The "environmental bonus" is a subsidy from the government and corresponds to the electricity tax for households.

21.5 MARKET DEVELOPMENT

21.5.1 Market Stimulation Instruments

In addition to the environmental bonus, a second market stimulation program, a 15% investment subsidy, began on July 1, 1997. The investment subsidy has a five-year budget total of SEK 300 million. By the end of 1998, the Swedish National Energy Administration had received applications for investment subsidies with a total investment value of SEK 7,900 billion. Total subsidies granted under the program amounted to SEK 135 million. Subsidies for 1998 alone totaled SEK 42.3 million. These projects had a capacity of 94.3 MW. The investment subsidy and the environmental bonus for wind turbines remain in effect for 1999.

Table 21.2 Price of Network Service and Electricity, Excluding Taxes, on January 1, 1998 in Sales of Electricity under the Terms of a Delivery Concession to Various Typical Customers

CUSTOMER TYPE	NETWORK SERVICES öre*/kWh			ELECTRICAL ENERGY öre/kWh		
	1997	1998	% Change	1997	1998	% Change
Apartment	41.1	42.3	2.8	29.2	29.0	-0.7
Single-family house without electric heating	36.2	37.1	2.5	27.6	26.8	-2.8
Single-family house with electric heating	21.6	20.7	-4.3	25.9	25.1	-2.9
Agriculture or forestry	22.5	21.7	-3.4	24.9	24.1	-3.3
Small industrial plant	16.5	14.8	-10.1	25.6	24.1	-5.9
Medium-sized industrial plant	9.3			24.4	23.1	-5.4
Electric-intensive industrial plant	2.6			23.4	22.0	-6.0

Source: "Prices of electrical energy and network service in 1998," E17 SM 980102, Statistics Sweden

*100 öre = SEK 1

21.5.2 Constraints

Public attitudes toward wind power, especially its impact on the landscape, is a very important factor that influences practically every wind project. Noise emission is also important, but largely as a technical problem. So far the impact on bird life has been minimal.

Objections from the military have also stopped many wind projects. The military sees risks for disturbances of military microwave links, radar, intelligence activities, and aircraft flying at low altitudes.

Public Attitudes

A series of investigations on public attitudes towards wind power plants has been carried out. The investigations have included both inhabitants and summer residents around the plants, and politicians and civil servants from the municipality. A majority of those interviewed had a positive attitude towards wind power. Among the summer residents, there were more doubts about wind power plants. Public attitudes are also being investigated in a research project, examining how attitudes can be improved, including public consultation in the permission process for wind power.

Noise

Noise is a subject frequently discussed in wind turbine projects. Assessments of wind turbine noise have shown that not only the sound level and its temporal pattern, but also several other factors are important for subjective responses. Work is continuing on how to describe the noise disturbances in physical terms. Research has started on how people experience different sounds/noises, and what kinds of sounds are preferred compared to others.

Disturbances to Military Activities

A research project is developing a valid model of the disturbances wind turbines cause to the military microwave links, radar, and intelligence activities. Thus far, the results show that the disturbance due to wind turbines on radar has been quite overestimated.

21.5.3 Institutional Factors

In April 1998, the Ministry of the Environment set up a government committee to analyze conditions for siting and permission procedures for wind farms in Sweden. The committee was also to report on the need for strengthening local electricity grids. A progress report was published in December 1998. It describes the present wind energy system, experiences from wind power exploitation and permission procedures, plans of the expanding wind energy enterprises, influences on the local environment, considerations in the planning and exploitation work, and the need for better wind resource mapping in the northern mountain areas and offshore. The committee also analyzes the visual experience of different wind turbine projects in different types of landscape. The final committee report will come out in June 1999.

21.6 GOVERNMENT-SPONSORED R, D&D PROGRAMS

21.6.1 Research and Development

Scope

The overall goal for the Swedish wind energy research program is to develop knowledge in wind energy so it will be possible to manufacture and develop wind turbines and utilize wind energy efficiently in the Swedish Energy system.

Financing

On July 1, 1998, a fully financed research program started with a three-year budget of SEK 46.8 million for 1998-2001. The budget has been increased since the previous period and the number of subjects of research has also been increased.

The subjects of research are meteorological data and power performance; aerodynamics and structural mechanics; loads and design; electric system and control technology; acoustics; and socio-technological aspects.

The work has mainly been carried out and administrated by the Wind Energy Programme VKK (VKK stands for wind energy—knowledge—competence). VKK was formed in 1994, and is led by the Aeronautical Research Institute of Sweden (FFA). More information can be found at the following WWW-page: http://www.ffa.se/windenergy/windenergy.html.

Research Topics

Some of the current research projects are presented here.

Direct-Driven Generators for Wind Turbines

The interest in direct-driven generators for wind turbines is increasing because they make the gearbox unnecessary. In Figure 21.3, a conventional drive train consisting of a four-pole induction generator with a gearbox and a direct-driven generator are shown. Without the gearbox, the cost can be reduced, the energy efficiency can be increased, and the total weight of the machinery can be reduced.

It is, however, not certain that all of these goals will be reached by using direct-driven generators. Because of the low turbine speed, 32 rpm for a 500-kW turbine, the rated torque becomes high. The direct-driven 500-kW generator has a rated torque of 148 kNm, which is as high as the rated torque of a turbo generator of 47 MW. Because of the high rated torque, direct-driven generators need a large diameter, and the losses at rated load will be high.

The purpose of this research has been to select a generator type, which can lead to small, light and efficient generators. Generators from 30 kW to 3 MW of the selected type have been designed and optimized.

Directly grid-connected synchronous generators of the conventional type are not suitable as direct-driven wind turbine generators. At 32 rpm, a generator needs 188 poles to generate 50 Hz. The pole pitch of electrically excited grid-connected generators cannot be much smaller than 200 mm. A smaller pole pitch leads to poor load angle damping and high excitation losses. The high pole number and the large pole pitch will lead to a large diameter, while the active stator length will be very short. The generator design will be very unfavorable and become very heavy and inefficient.

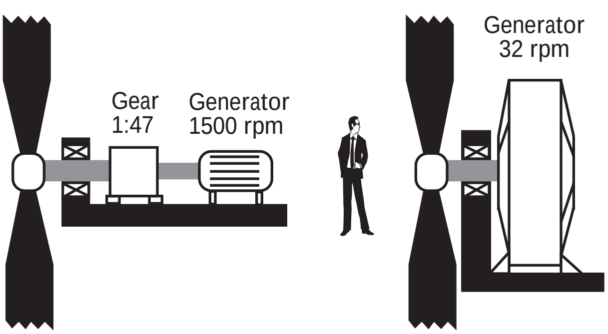


Figure 21.3 A Conventional Generator with Gear and a Direct-Driven Permanent Magnet Generator, Both for a 500-kW Turbine

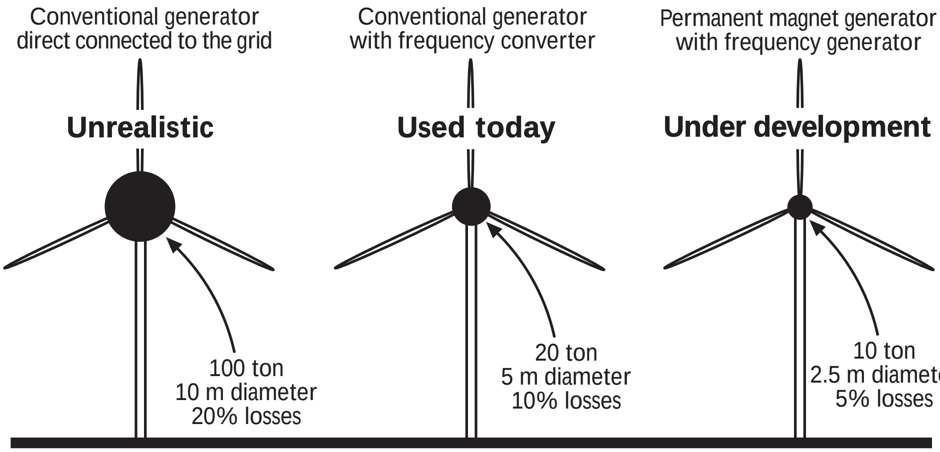


Figure 21.4 Comparison of Three Different Types of 500-kW Direct-Driven Generators

If the generator is connected to a frequency converter instead of directly to the grid, the diameter can be decreased. The pole pitch cannot be reduced much since that would lead to large excitation losses, but the frequency can be allowed to be less than 50 Hz. The diameter of this generator type will be approximately half of the diameter of the directly grid-connected generator, and both the weight and the losses will be reduced a great deal. This generator type is used today. Figure 21.4 compares it to a conventional directly grid-connected generator and a permanent magnet generator.

Using permanent magnets, instead of electrical excitation, eliminates the excitation losses completely and, as a consequence, the pole pitch can be reduced. The small pole pitch and the elimination of the excitation losses make it possible to reduce the diameter and weight of the generator. The efficiency will also be increased.

To achieve a high efficiency, low active weight, and a small diameter, the generator should have permanent-magnet excitation and be connected to a frequency converter. To keep the generator small, the frequency converter should have a forced-commutated rectifier. The energy efficiency of a direct-driven generator can be higher than the efficiency of a conventional induction generator and gearbox, although the full-load efficiency is lower.

Wind Conditions Offshore

Ongoing experimental and modeling research is increasing our understanding of mean wind and turbulence conditions both offshore and in coastal areas.

Results so far show that conditions in the marine atmospheric boundary layer are affected by sea waves to a much higher

Table 20.4 Project Data Bockstigen, Valar 2.5 MW

Capacity	5x500 kW
Calculated average wind, 40 m height	8 m/s
Calculated annual electricity production	8 GWh
Calculated construction cost	32.2 million SEK

degree than expected. For example, as a consequence of the interaction with the waves, the wind shear offshore may vary over a wide range, from a large shear corresponding to conditions over forested areas, to a very small shear as expected over smooth surfaces.

In a number of experiments in the Baltic Sea area, it has been found that wind maxima at low heights (50-300 m, so-called low-level jets) are very common, and that these maxima affect both the mean wind climate and turbulence conditions to a high degree offshore. One important origin of the jets is inertial oscillations originating at the coasts for offshore flow when unstable thermal conditions prevail in the atmospheric boundary layer over land, while at the same time the stratification is stable over the sea. As the Baltic Sea is surrounded by land in all wind directions, we may thus expect low-level jets over the Baltic Sea to be found very often, especially during spring and early summer. We think that they affect the offshore wind climate over the whole Baltic Sea area.

Figure 21.5 Meteorological Tower at Östergarnsholm, Gotland.

It has been shown both in experimental data (aircraft measurements together with tower data and balloon measurements) and in modeling results, that it is not only the low-level jets which may affect the winds over large offshore areas, but also in the case of very stable conditions over the sea, sea breeze circulations and with offshore flow may have effects. It has been verified with both data and modeling results that the offshore wind field may be affected to distances of 100 km from land or more. That is the distance between the Swedish mainland and the island of Gotland.

Wind Energy Research at Sweden's First Offshore Wind Farm

Partially financed by THERMIE, five stall-controlled, semi-variable speed, 500-kW wind turbines were built and put into operation by Vindkompaniet in 1997–1998. The location is Bockstigen, 3 km west of Burgsvik and 3 km south of Näsudden in the Southwest corner of the island of Gotland in the Baltic. A technical evaluation, primarily focusing on the electrical characteristics of the connecting weak grid, is required within the THERMIE Programme. A more comprehensive technical evaluation, described below, is to be carried out by the Swedish National Energy Administration.

The foundations are of the monopile type, which have the potential for lowering the installation cost, thus making offshore installations more cost effective. Vertical holes 10 m deep were drilled into the limestone rock and the tubular steel structures were put into the holes and secured by concrete.

The monopile and tower of one of the turbines have been equipped with strain gauges at several depths and heights. Transfer of tower loads to the rock as well as wave and ice loading are examples of issues to be analyzed. Also the evaluation of the dynamic behavior of the semi-variable speed turbine is of interest as the dynamic properties for a monopile-mounted wind turbine are expected to be significantly different from a “standard” onshore-mounted turbine. All mechanical measurements are continuously recorded on shore at 20 Hz, via a 5-km optical fibre cable.

The electrical output and wind speeds at the nacelle are continuously recorded and will be evaluated regarding a) energy content relative to nearby onshore locations, b) wake effects, c) usability of nacelle wind speed anemometers for the assessment of power performance in “simple” terrain, and d) electrical characteristics.

A 40-m meteorological mast is to be placed in the wind farm enabling continuous measurement of atmospheric conditions including wave height and water velocity, power performance, and wake effects. The foundation chosen for the meteorological mast is of the lattice type secured to the bottom by the use of cemented rods. As this type of foundation might be usable also as foundation for offshore wind turbines, it has been equipped with strain gauges as well. There are three masts from which meteorological data are continuously recorded; a 145-m inland mast, a 60-m mast onshore, and the 40-m mast mentioned above.

21.6.2 MW-Rated Turbines

Näsudden II

Since it began operation, the 3000-kW Näsudden II has generated 25,088 MWh during 23,837 operating hours as of December 31, 1998. Its generation during 1998 was 5,465 MWh and availability was 85%.

Nordic 1000

Since start up, the 1-MW Nordic 1000 has generated 5,888 MWh during 21,285 operating hours as of December 31, 1998. During 1998 it generated 2,426 MWh and its availability was 95%.

21.6.3 Offshore Siting

Nogersund

Since 1991, there has been a research program concerning the impact on the environment from the 220-kW offshore wind power station at Nogersund.

Bockstigen, Valar

An offshore demo-plant began operation 4 km offshore of Näsudden on Gotland. The project consists of five plants, each 500 kW. The Bockstigen Valar project is sponsored by EU (THERMIE) and the Swedish National Energy Administration. The turbines delivered their first electricity to the main grid in March 1998.

Utgrunden

The company Vindkompaniet has applied for permission for a 10-MW wind energy project in the sound between the city of Kalmar and the island Öland.

Lillgrund

In the sound between Sweden and Denmark, the company Eurowind has applied for permission for an offshore wind energy project with 48 wind turbines of the 1.5-MW size.

Offshore 3 MW turbine farm

West of the city of Karlskrona in southeast Sweden, the utility Vattenfall has begun a feasibility study for an offshore project with 3 MW wind turbines. In the city’s preliminary oversight, planning for the offshore site includes about one hundred large MW wind turbines.

21.6.4 Complex Terrain and Cold Climate Siting

Suorva in Lappland

At one of its large hydro-power dams in the Lule River valley, the utility Vattenfall erected a 600-kW wind turbine with a Finnish-Danish non-icing system in the blades (see Figure 21.6) in October 1998. Suorva is situated 100 km north of the Arctic Circle. Since 1995, a 35-m mast with four anemometers has documented a good local wind resource equivalent with the island of Gotland. An evaluation program will be operated for three years. The project is sponsored by the Swedish National Energy Administration.

Rodovålen in Härjedalen

The company Agrivind has erected three wind turbines on a mountain top in Härjedalen in the middle of Sweden. One turbine has a capacity of 750 kW and two have a capacity of 600 kW each. The objective of the project is to contribute to the development of wind power technology in cold climates. The project is sponsored by the Swedish National Energy Administration.

21.6.5 International Collaboration

International cooperation has increased significantly during the last years. Most of the cooperation is carried out in the framework of European Union and International Energy Agency. Sweden participated in a number of JOULE II and JOULE III projects during 1996. The experiences from these types of projects are very positive. They provide the opportunity to exchange and develop knowledge in a structured way. The joint financing also makes possible projects which otherwise could not have been carried out. Swedish researchers and companies are therefore looking forward to continued work within IEA and the EU 5th framework program.

Figure 21.6 Suorva 600 kW

CHAPTER 22

22.1 GOVERNMENT PROGRAMS

22.1.1 Aims and Objectives

Policy.

Former government policy has been to stimulate the development of new and renewable energy sources wherever they have prospects of being economically attractive and environmentally acceptable in order to contribute to the following.

- Diverse, secure and sustainable energy supplies,
- Reduction in the emission of pollutants and,
- Encouragement of internationally competitive industries.

The present government proposes a new and strong drive to develop renewable energy sources in line with its manifesto commitment and believes in increasing the amount of the UK's energy resources that come from renewable energy. A policy review announced by the Minister for Science, Energy and Industry is considering what will be necessary and practicable in order to achieve 10% of the UK's electricity needs from renewables by the year 2010. An announcement is expected during 1999.

22.1.2 Strategy

The government has initiated a market enablement strategy to implement its policy, stimulating the development of sources and industrial and market infrastructure so that new and renewable sources are given the opportunity to compete equitably with other energy technologies in a self sustaining market. For wind energy, the strategy seeks to encourage its uptake by the following actions.

- Stimulating an initial market via the Non-Fossil Fuel Obligation,
- Stimulating the development of the technology as appropriate,
- Assessing when the technology will become cost effective,
- Quantifying the associated environmental improvements and disbenefits,
- Removing inappropriate legislative and administrative barriers,
- Ensuring the market is fully informed.

The government also seeks to encourage internationally competitive industries to develop and utilize capabilities for the domestic and export markets.

Market Stimulation—There is a requirement on the electricity supply companies in the UK to provide a proportion of their supply from renewable energy sources. The requirement is set out in the Government's Renewable Energy Obligations. There are separate obligations for England and Wales (the Non-Fossil Fuel Obligation—NFFO), Scotland (the Scottish Renewables Obligation—SRO) and Northern Ireland (the Northern Ireland Non-Fossil Fuel Obligation—NI-NFFO). The additional costs incurred by the companies in buying non-fossil fuel power to meet their obligation are passed on to the consumers.

In September 1998, the order for the fifth round of bidding under the Non-Fossil Fuel Obligation was announced adding a further 867 MW of contracted capacity. A similar announcement of the third Scottish Renewables Order is expected in early 1999.

Government R, D and D Program

The government (through its Department of Trade and Industry—DTI) supports a program aimed at helping industry to improve its market share both at home and abroad and nearly all expenditure is now on the development, demonstration, and monitoring of projects to help reduce the cost of wind energy and improve our competitiveness. The program is also addressing key non-technical barriers, including public acceptability, electrical integration, and environmental impact. An essential adjunct is dissemination of information arising from both directly funded work and from projects in the Renewable Energy Orders.

22.1.3 Targets

As discussed above, during the year a policy review of what would be necessary and practicable in order to achieve 10% of the UK's electricity needs from renewables by the year 2010 was instigated. An announcement is expected during 1999.

22.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

22.2.1 Installed Capacity

A total of 13 MW of rated capacity were installed in the UK during the year. This brought the total installed capacity under the Renewable Energy Orders at the end of 1998 to 323 MW (756 turbines). Figure 22.1 shows the growth of this capacity with time.

During 1998, the following progress was made on each of the Renewables Orders.

NFFO (England & Wales). Only two of the projects awarded contracts under NFFO-3 were commissioned with a total capacity of 12.4 MW. In addition, a single 600-kW project was completed with a NFFO-4 contract. In September 1998, the fifth and largest renewables Order was announced with a total contracted capacity of 876 MW.

Northern Ireland NFFO. A single 1-MW project with an NI NFFO-2 contract was under construction, but not yet commissioned by the end of 1998. The total installed capacity now operating is 30 MW.

Scottish Renewable Energy Order (SRO). No new wind farms were commissioned during 1998, leaving the total installed capacity at 51.8 MW. An announcement on the third round of the SRO is expected in early 1999.

Table 22.1 summarizes progress to date in fulfilling the Renewable Energy Obligations.

22.2.2 Installed Conventional Capacity

The total capacity of plants supplying the national grid is around 60 GW.

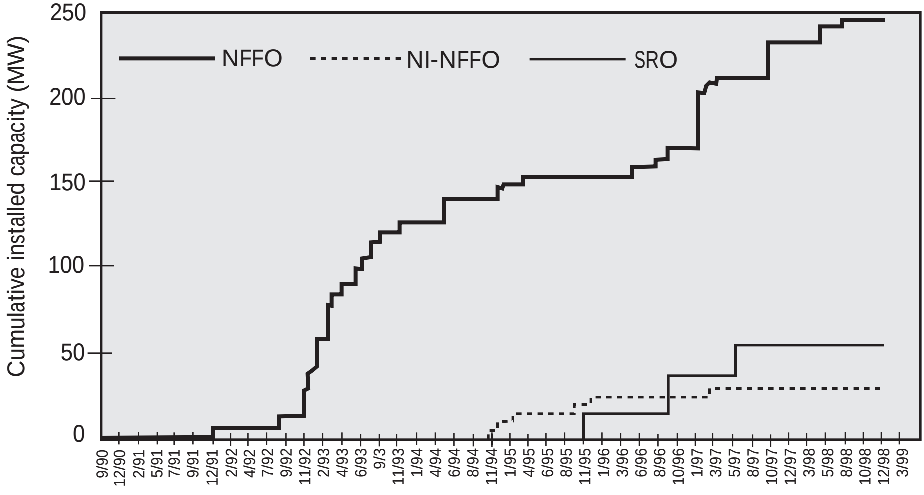


Figure 22.1 Rate of Installation of Wind Energy Capacity Under the NFF), NI-NFFO, and SRO

Table 22.1 Rate of Installation of Wind Energy Capacity Under the NFFO, NI-NFFO, and SRO

ORDER	EFFECTIVE START DATE	NO. PROJECTS CONTRACTED	NO. PROJECTS OPERATING	INSTALLED CAPACITY MW DNC	INSTALLED CAPACITY MW RATED (approx.)	NO. TURBINES CAPACITY MW RATED	INSTALLED
NFFO-1	1990	9	7	12.21	28.0	27.6	75
NFFO-2	1992	49	25	82.43	192.0	126.0	365
NFFO-3 (>3.7 MW)	1995	31	7	145.92	339.0	75.5	140
NFFO-3 (<3.7 MW)	1995	24	6	19.71	46.0	11.9	23
NFFO-4 (>1.8 MW)	1997	48	—	330.40	768.0	——	
NFFO-4 (<1.8 MW)	1997	17	—	10.40	24.2	0.6	1
NFFO-5 (>2.3 MW)	1998	33	—	340.16	791.0	—	—
NFFO-5 (<2.3 MW)	1998	35	—	27.92	64.9	—	—
SRO-1	1995	20	4	45.60	106.0	51.8	92
SRO-2	1997	7	—	43.60	101.5	—	
NI-NFFO1 60	1994	6	5	12.66	29.0	30.0	

Note 1: DNC is declared net capacity, and takes in to account the intermittent nature of wind energy.

Note 2: Two adjacent NFFO 3 projects totalling 33.6MW (rated) and consisting of 56 turbines have had their start date revised to 1997 from 1996 since last year's report.

22.2.3 Plant Type

The capacity installed during 1998 consisted of 25 of 25 machines, exclusively of Danish manufacture. The machines were installed on three separate developments including one wind farm of 20 machines rated at 500 kW each, one farm of four machines rated at 600 kW each and one development of a single machine rated at 600 kW.

22.2.4 Forms of Ownership

The major UK electricity generators continue to take ownership of most of the new installations. This confirms the trend that, as the reliability and performance of wind farms becomes proven, corporate investment is increasing from, in particular, the electricity generating and distribution companies. In many cases the operators of the wind farms continue to be the original development companies operating under contract to the owners.

22.2.5 Energy Output

For the year from January 1 to December 31, 1998, the total energy output from projects in NFFO, NI-NFFO, and SRO were 557.3 GWh, 99.2 GWh, and 148 GWh, respectively, with a national total for the year of 805.2 GWh. The quarter-by-quarter output from the projects is shown in Figure 22.2. It is estimated that non-NFFO turbines produced 12 GWh.

22.2.6 Technical Performance

The technical performance was good with high availabilities (>95%) and average load factors approaching 30% being reported from the wind farms. The wind farms in Northern Ireland and Scotland performed particularly well with load factors approaching 0.50 in some months due to the good wind regimes.

22.2.7 Operational Experience

There is an unconfirmed report of a blade loss on a single WEG MS3-400 turbine at a Welsh wind farm. No other operational difficulties were reported.

22.3 MANUFACTURING INDUSTRY

22.3.1 Wind Turbine Manufacturers

The UK's leading wind turbine and blade manufacturer, WEG, was taken over by NEG-Micon in March 1998. NEG-Micon has retained a core team of engineers in the UK. In addition, the wood laminate blade business is now called Aerolaminates. The MS4 600 has not gone into production. In other developments, Renewable Energy

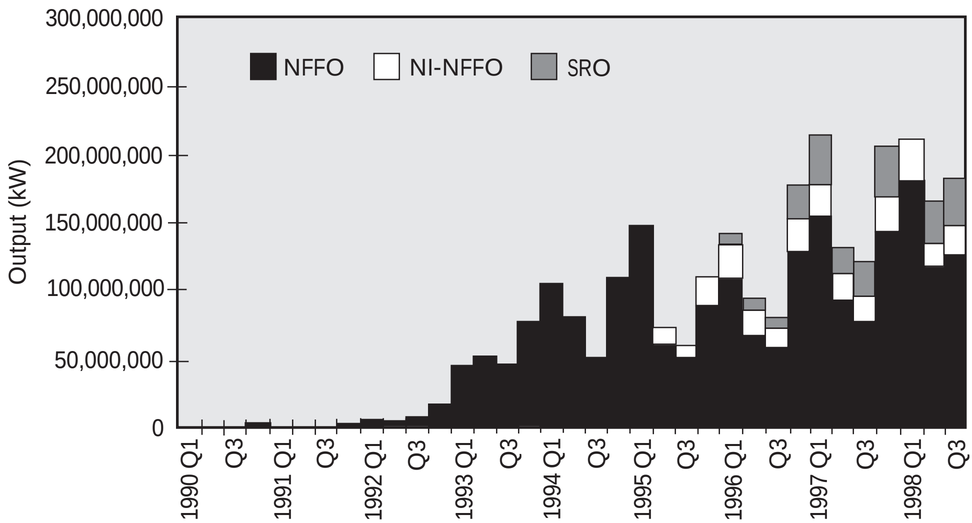


Figure 22.2 Quarterly Wind Energy Production from NFFO, NI-NFFO, and SRO

Systems sarted to build a prototype of their 1-MW turbine.

22.3.2 Other Industries

Component Suppliers.

The unfavorable exchange rate and a declining home market further consolidated the market for component suppliers. Towers and castings manufactured in the UK continued to be supplied to foreign turbine manufacturers. The wood-composite blade manufacturer Aerolaminates, continued to increase its business with full order books for the year.

Consultants.

There is a continuing demand for consultants in site exploration, performance and financial evaluation, planning applications, and environmental impact statements as successive tranches of the Renewable Energy Obligations are announced.

22.4 ECONOMICS

22.4.1 Electricity Prices

For NFFO-4 contracts (awarded in 1998, up to 15 years in duration) the capacity weighted average bid-in price of large projects (>2.3 MW) was £ 0.0288/kWh (lowest £ 0.0243/kWh, highest £ 0.0310/kWh) while for small projects in NFFO-5(<2.3 MW) the bid-in prices averaged £ 0.0457/kWh (lowest £ 0.0409/kWh, highest £ 0.0495/kWh). The reductions in average bid price compared to the previous tranche of contracts for NFFO-4 (large and small) were 18% and 9%, respectively.

By comparison, the domestic cost of electricity varies from 7 to 8.5p/kWh while industrial consumers can expect to pay 4.5 to 8.5p/kWh.

22.4.2 Invested Capital

On the assumption that the average installed cost of the wind plant already installed was £ 1000/kW of rated power up to 1996 and £ 800/kW in 1997 and 1998, the total invested capital is circa £ 306 million. Assuming that the average cost of the wind plant installed during 1998 was £ 800/kW, the capital invested during the past year was circa £ 10.4 million.

22.4.3 Turbine and Project Costs

Based on data from developers, the ex-factory cost of wind turbines available for UK projects is around £ 480-580 per kW of rated power. For current projects, the total project cost for wind farm developments was estimated to be about £ 750-850 per installed kW and is therefore little different from 1997 price levels.

22.5 MARKET DEVELOPMENT

22.5.1 Planning and Grid Issues

Securing planning permission has become the greatest obstacle to the development of wind energy in the UK. Virtually all projects submitted for planning approval in 1998 have been unsuccessful in getting this approval. The British Wind Energy Association estimates that obtaining planning permission usually takes more than two years and costs developers more than £ 100,000. Of the 20 appeals heard since the beginning of 1994, only four have been successful.

In the short term, developers are able to find suitable connection points for their projects. However if more ambitious medium term targets are adopted then consideration will need to be given on how best to incorporate a relatively large amount of embedded generation in to the grid system.

22.5.2 Institutional Factors

Planning.

The government continued to encourage local authorities to establish local structure plans which include renewable energy developments. The government is now monitoring the local authority structure plans to review how national renewable energy policies are being incorporated into local plans. The success of applications for planning permission for renewable energy projects is also being monitored.

Certification.

Standards for and certification of wind turbines continue to receive attention. The UK industry with the support of the DTI, continues to be increasingly involved in national and international activities in these areas, especially with the work ongoing in the European Union.

Machine Certification requirements.

The only certification requirement for wind turbine installations in the UK is under the EU Machinery Directive. Standards and certification are currently being considered by the British Standards Institute as input to possible IEC recommendations.

22.5.3 Impact of Wind Turbines on the Environment

Visual intrusion.

The visual impact of turbines continues to be the prime concern in the development of UK wind farms due to developers seeking the best wind speed sites on high ground, which are often in sparsely populated areas of scenic beauty. It is however to be expected that visual impact would also be the main issue in landscapes of less national importance. The conflict between the environmental benefits of wind energy and loss of landscape value continues to be a major factor in obtaining planning consent for a wind farm development. As the number of wind farms increases, the question of cumulative impact is also requiring more consideration. Only one project received consent during 1998.

Noise.

Another concern is that of the noise generated by wind turbines, largely because of the high population density of the UK and dispersed settlement patterns. A noise working group was set up by the DTI to review recent experience, to define a framework to measure and rate noise from wind turbines, and to provide indicative noise levels for best practice. Following the publication of the Noise Working Group’s guidelines in September 1996, noise has become less of an emotional issue. It is now widely accepted that, though requiring consideration at the planning stage, wind farm noise can be properly controlled and monitored according to requirements laid down in planning conditions.

Public attitudes.

Public attitude toward wind turbines continues to be a controversial subject. Despite several surveys indicating that local support for wind farms is high, there is still widespread adverse comment in the press from both individuals and national bodies. Organized objector groups, co-ordinated nationally, are believed to be largely responsible for the adverse press. A major opinion poll is planned for 1999.

Radar.

The development of some projects has been delayed while concerns from the Ministry of Defence over the effect of wind farms on radar performance are investigated.

22.5.4 Financing

Type of funding available.

Financing for wind farms is obtained largely from corporate investors and banks though there is a small amount of private investment. There is no public funding available for wind farms as the premium prices from the Renewables Energy Orders are considered sufficient incentive.

Typical financial interest rates.

Interest rates asked by banks are typically 1.5% above the London Inter Bank Offered Rate (LIBOR). Equity / debt ratios are typically 25 / 75, with investors requiring a post-tax return on equity of typically 15% to 25%. Clearly these figures can vary considerably from project to project. Alternatively, larger companies will often finance a project themselves off the balance sheet and will expect a real rate of return of 8% to 12%, dependent on the associated risk.

22.6 GOVERNMENT-SPONSORED RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAMS

22.6.1 Funding Levels

Around £1.7M of the budget for DTI's Programme on New and Renewable Energy was allocated to wind energy development during 1998 which is equal to funding for the previous year.

22.6.2 Priorities

The government continued to work in a cost-shared program with industry, but as the technology achieves maturity this is subject to review. The trend is towards decreasing contributions from government.

22.6.3 R&D Results in 1998

A series of generic projects were recruited during 1998 to address barriers to deployment. These barriers include cumulative impact, visual intrusion, and integration with the national electricity distribution system.

22.6.4 Offshore

The Minister responsible for the UK government's New and Renewable Energy Programme has invited responses from the wind industry on suitable ideas to develop the offshore wind resource. An announcement on this process is expected in 1999.

22.6.5 International Collaboration

Formal international collaboration in the DTI's wind energy program is through the IEA and the European Union (EU) programs. The DTI encourage UK contractors to participate in EU-funded projects, and the DTI and the EU programs are considered to be complementary. UK contractors can receive supplementary funding from the DTI, where the work is relevant to the DTI program.

CHAPTER 23

23.1 GOVERNMENT PROGRAMS

The Wind Energy Systems Program, conducted by the United States Department of Energy (DOE), focuses on research and development (R&D) efforts to help U.S. industry develop wind energy technology as an economically viable energy supply option that is competitive in the growing domestic and global markets. In addition, DOE supports the deployment of commercial wind systems and other renewable technologies by providing financial incentives that are discussed later in this report.

Renewable energy application projects, some of which include wind systems, are supported separately by the United States Department of Defense, the Environmental Protection Agency and the Agency for International Development. However, the largest and only federally supported Wind Energy R&D Program is operated by DOE and is discussed in detail below.

23.1.1 Aims and Objectives

The general objective of the DOE Wind Energy Program is to work in partnership with industry and electric utilities to establish leadership in the understanding, development and use of wind turbine technology to achieve multi-regional application of wind systems. Specific objectives of the DOE Wind Energy Program are

- to develop improved wind energy systems performance and reliability,
- to participate in development of international consensus standards and U.S.-based wind equipment certification capabilities, and
- and to continue research on the basic science needed to improve future wind energy technology, components, and designs developed in close cooperation with U. S. industry, for both domestic and international market applications.

23.1.2 Strategies

The strategy used in the DOE Program is to conduct research that expands the knowledge base, explores new and innovative systems, and supports the cost-shared development and testing of improved, lower-cost turbines needed before widespread markets can be developed. DOE National Laboratories provide technical management and direction for the program operated with industry, electric utilities, universities, and other research organization partners that are selected through open competition. New technology developed under this effort is field tested, evaluated, and verified in projects that are cost-shared by the users. In some cases, projects are supported by financial incentives provided by the federal government and some state governments, to encourage commercial deployment of wind power plants by private industry and electric utilities.

The DOE Wind Energy Program is structured into the following three areas.

1. Applied Research—to develop the basic wind energy sciences and technology,
2. Turbine Research—to develop and test advanced wind turbines in various sizes from less than 10 kilowatts (kW) to more than one megawatt (MW), and,
3. Co-operative Research and Testing—to support industry in concept evaluation, field testing and initial deployment of new wind energy systems and technology. R&D efforts are focused at the National Wind Technology Center (NWTC), at the National Renewable Energy Laboratory (NREL), located in Golden, Colorado.

Their work is designed to develop and prove new technology and to minimize the technical, economic, and institutional risks for U.S. companies deploying advanced wind energy technologies.

23.1.3 Targets

The specific DOE cost goal for utility-scale, grid-connected wind power systems is to produce electricity at a cost of $0.025/kWh by 2002 at good wind sites. This target includes all turbines, land, and the balance of station costs for a 50-turbine wind power plant project located near power transmission lines.

To meet the goals of the DOE program, it is necessary to reduce wind energy system cost and improve performance so wind systems can be directly competitive with fossil fuel energy sources on a life-cycle basis. With the projected improvements in wind technology and the expected energy markets, it is estimated that an additional 1,000 MW of wind systems will be installed in the United States in less than five years, and that, by 2010, installed domestic capacity will reach 10,000 MW. An informal target is that U.S. industry will supply 25% of global markets by 2005.

The DOE cost goal for the small turbine development program is to significantly reduce the cost of energy to less than $0.10/kWh from machines with peak power ratings from 5 to 40 kW. Specific goals depend on the type of turbine and the planned operating environment and application requirements.

23.2 COMMERCIAL IMPLEMENTATION OF WIND POWER

One of the fastest growing markets for large-scale wind power plants is in the United States. During 1998, the installed capacity in the United States increased to about 1890 MW, up from 1743 MW at the end of 1997. New installations were mainly in the midwestern section of the country (See Figure 23.1). Most of the new turbines were in the 600 to 750-kW size range.

One major 107-MW project is located at Lake Benton, Minnesota (See Figure 23.2). It was built by Zond Energy Systems and began operating in August 1998. This is currently the largest single wind power plant in the world.

During 1999, it is projected that an additional 600 MW will be installed, not including re-powering projects, where old outdated machines are replaced with modern turbines.

Energy production from all wind systems in the U.S. during 1998 was estimated to be 4.5 terraWatt-hours, assuming that the average plant capacity factor was 27%.

There are several reasons for the renewed growth in wind power in the United States. First, new and better turbines are now available. Second, utility restructuring is progressing. And even more important, at the national level the wind energy production tax credits are currently scheduled to be eliminated for plants installed after June 30, 1999. The DOE proposed to extend the credit an additional five years, but this extension was not adopted. Thus many developers are accelerating installations to qualify for the 10-year period of tax incentives. Currently the tax credit on profits is $0.017/kWh, adjusted annually for inflation. For municipal utilities that do not pay taxes, there is a payment of $0.017/kWh from DOE (subject to funds availability) under the Renewable Energy Production Incentive. To qualify, a facility must be constructed before September 30, 2003. The payment period is scheduled to end with fiscal year 2013.

Off-grid commercial applications of wind systems are also increasing in the United States. Under a project for the U.S. Navy, the National Wind Technology Center is assisting in a project that may eventually

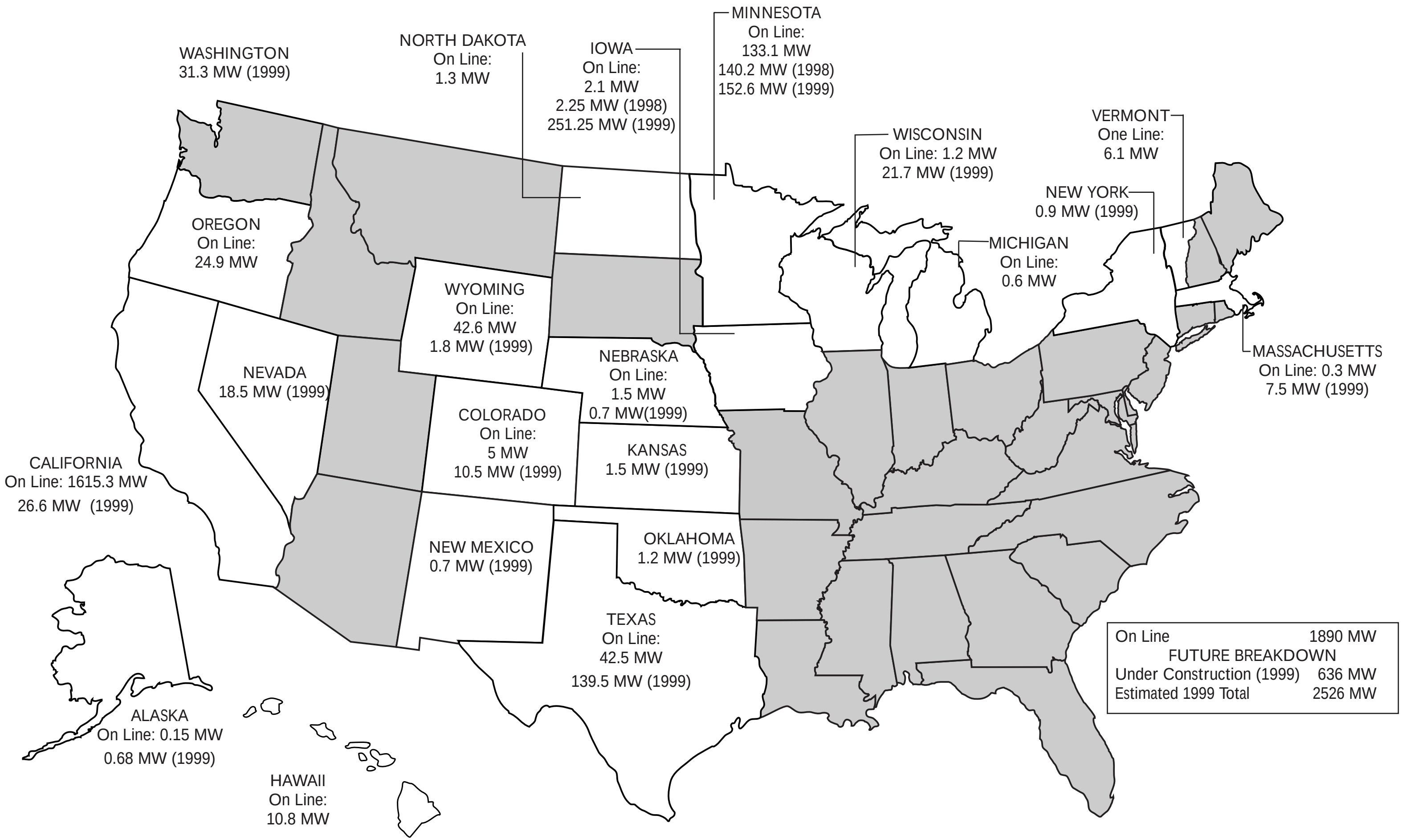


Figure 23.1 Wind Power Plants in the United States: Capacity On-Line by the End of 1998 and Installations Planned for 1999

Figure 23.2 Wind Power Plant at Lake Benton, Minnesota Using Zond Energy Systems 750-kW Turbines

add nearly 1 MW or more of wind systems to an existing 10-MW diesel-based power system located on San Clemente Island off the southern California coast (See Figure 23.3). Two 225-kW turbines have been installed and are operating while a third unit will be added early in 1999.

Additional military and government-owned off-shore sites are being evaluated for wind / diesel hybrid systems. The wind / diesel installation in Kotzebue, Alaska is partially complete. Three 50-kW Atlantic Orient Corporation (AOC 15-50) turbines have been installed and are undergoing extensive operational tests at this remote village located on the western coast of Alaska, just north of the Arctic Circle. Seven additional AOC 15-50 turbines will be installed at the site during 1999, along with a prototype of the Northern Power Systems 100 kW North

Figure 23.3 Wind / Diesel Installation on San Clemente Island, California

Wind Polar Turbine discussed later in this report.

Export sales of U.S.-built turbines are also increasing. Zond Energy Systems has completed installations in Europe and China. Bergey Windpower has installed turbines in Russia and completed a joint venture agreement to build turbines in China.

Re-powering some of the older wind plants is beginning to occur in California. Some of the turbines that are approaching 20 years of operation are being replaced with larger and more efficient machines. During 1998, hundreds of older turbines, less than 100 kW each, were replaced with modern 600-750-kW turbines. Spacing is often increased between these larger turbines to minimize wake effects on power production. In addition, some of the project sites have capacity limitations. Having fewer turbines has reduced the visual impact of some projects. Data are being collected on increases in energy production from the re-powered projects.

23.3 MANUFACTURING INDUSTRY

The wind industry in the United States includes about eight companies currently manufacturing turbines and numerous businesses building components, developing projects, and providing engineering services and related equipment. Fluctuations in both the domestic and international markets have forced some companies out of business, but some of the larger European wind turbine manufacturers are establishing assembly and component manufacturing plants here, creating jobs for U.S. workers.

Wind turbines developed under the DOE program meet international standards for design and performance. Until recently there was no recognized third party, U.S.-based, certification agent. However, Underwriters Laboratories (UL), which has a long history in the field of electrical equipment testing and rating, has decided to develop a wind turbine certification program in partnership with the National Renewable Energy Laboratory. UL ratings are recognized worldwide on hundreds of other products, including fire and security equipment, insulation, fuses, transformers, relief valves and other safety systems, as well as many other types of industrial and commercial products. UL plans to coordinate its background in electrical equipment certification and manufacturing quality reviews (ISO 9000) with NREL's turbine testing expertise to implement the certification program that will meet International Electrotechnical Commission standards (IEC 61400 Series).

Until recently, U.S. manufacturers relied solely on European-based agents to certify that their machines met the internationally accepted standards. This was often a slow, time consuming, and expensive process. Currently, U.S. utilities, wind plant developers and other U.S. customers do not require certification of entire wind systems, but certification is needed to enter some of the international markets. As a result, U.S. manufacturers supported and encouraged NREL to participate in the development of the IEC and other harmonized international standards. In the U.S. domestic markets, customers tend to rely more on manufacturers' track records, warrantees, and independent assessments to reduce their risk. There are no plans to significantly change that approach.

23.4 ECONOMICS

The DOE Wind Systems Program has made major progress in reducing the cost of wind-generated electricity but important targets have been set for further improvements. Since 1980, the cost of energy from wind systems has been reduced from $0.35/ kWh to less than $0.04/kWh for large wind plants operating at good wind sites with annual average wind speed of 6.7 meters per second (m/s) (15 miles per hour), measured 10 m above ground. At current costs, wind energy can compete in selected markets in the United States where new generating capacity is needed and fossil fuel cost is high, or where there are other incentives available to encourage the use of clean energy sources. An example of the latter is in the State of Minnesota, where additional wind power capacity was mandated to offset the need for storing nuclear plant wastes.

Additional cost reductions for wind energy are considered to be both necessary and technically feasible. This is the basis for the DOE goal of $0.025/kWh for advanced wind turbines by 2002. For wind energy to compete in the huge windy regions of the midwestern United States, costs must still be reduced significantly. This is especially true in the central region of the country that is dominated by coal and gas-fired plants burning low-cost fuels and operating in this era of aggressive competition and least-cost economics.

DOE and the Electric Power Research Institute (EPRI) teamed up to characterize the future characteristics and costs for wind and other renewable energy systems. By 2010, wind was found to have by far the lowest Cost Of Energy (COE), compared to other intermittent technologies (solar thermal and photovoltaics) and was directly competitive with geothermal energy, the lowest cost "dispatchable technology." The basis for these estimates and the projected evolution of wind and other renewable energy systems are discussed in a report titled *Renewable Energy Technology Characterizations* that is available on the DOE Office of Power Technologies (formerly called the Office of Utility Technologies) web site at: www.eren.DOE.gov/.

23.5 MARKET DEVELOPMENT

The surge in market development in the United States is expected to continue until the Federal tax credits expire. Unless there are changes made with new tax legislation, the tax credits apply only to projects that are completed prior to

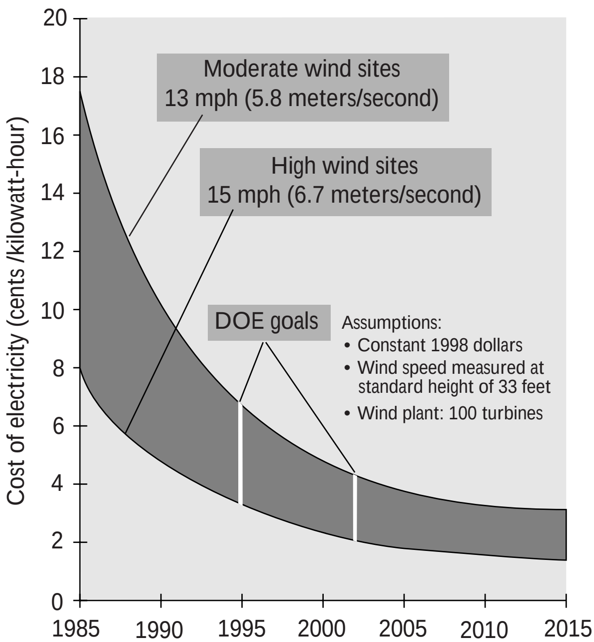


Figure 23.4 Trends in the Cost of Wind Energy

June 30, 1999. Several proposals have been made for extending the tax credits up to five more years. Discussions on this are continuing. There are a variety of incentives that are implemented independently at the state level. These incentives include price premiums (up to $0.02/kWh) for “green energy” such as wind, wavers or reductions on property taxes for wind energy facilities, holidays on sales taxes for wind equipment, and mandatory additions of wind power or other renewables to utility generation portfolios. Additional details are included in the IEA 1997 Annual Report, page 161.

Restructuring of the U.S. utility industry is proceeding in most states. Generally, electric utilities are being required to reorganize into one of two types of companies. They may reorganize into distribution companies (DistCos), which are either regulated, investor-owned utilities or municipally (publicly) owned utilities; or they may reorganize into unregulated generation companies (GenCos). These business structures are discussed in the previously mentioned DOE/EPRI *Renewable Energy Technology Characterizations* report. There is growing interest in distributed generation, often owned and operated by Independent Power Producers (IPPs). These new structures could help to encourage the use of wind and other renewable energy systems, but there is still substantial uncertainty regarding costs, generation ownership rules and procedures, and their impacts.

23.6 DOE-SPONSORED PROGRAMS

The overall mission of the Wind Energy Systems Program is to enable U.S. industry to complete the research, testing, and field verification needed to fully develop advanced wind energy technologies that are cost-effective, reliable, and competitive in international markets. DOE works with industry under the following program categories: applied research, turbine research, and cooperative research and testing. The program funding was $32.1 million in Fiscal Year 1998 and is $34.8 million in 1999.

Most of the wind energy R&D activities are conducted at the National Wind Technology Center (NWTC), located on a 280-acre site near Golden, Colorado. Supporting research is also performed at Sandia National Laboratories in Albuquerque, New Mexico. The NWTC conducts a wide range of basic wind energy research, component development and testing. In addition, complete system verification provides test data that can be used by industry and the Underwriters Laboratories for the turbine certification needed for some overseas markets.

The NWTC includes several experimental turbines for the study of unsteady aerodynamics and variable-speed operation, a turbine blade structural test facility and an industrial user facility. It also includes a hybrid power system test facility, that integrates wind turbines with other renewable power systems and two 60-kW diesels in simulated village power applications. The 600-kW Advanced Research Turbine (pictured in the 1997 IEA Annual Report) is being instrumented for full-scale component and system testing.

Blade structural testing facilities have been expanded to accommodate larger blades up to 135 feet long (See Figure 23.5). Fatigue testing of blades can now be done in two directions with load actuators up to 20,000 pounds force. The new stronger mounting frame will accommodate up to 10 million foot-pounds torque for bending and buckling testing of blades and sub-components.

Dynamometer load testing equipment is also being installed that will allow full power testing of complete wind turbine drive systems up to 1.5 MW. The NWTC has become one of the most comprehensive

Figure 23.5 Wind Turbine Blade Structural Testing at the National Wind Technology Center

wind energy research facilities in the world.

23.6.1 Applied Research Program

Applied research focuses on those technical elements that are critical to a clear understanding of the physics associated with wind energy technology. Among the elements is research on the detailed structure and dynamics of air motion in the boundary layer near the earth's surface, where wind turbines must operate. Aerodynamics is also studied to allow the conversion of the power in the air into useful forms. Structural dynamics are examined to predict the effects of turbulence on the turbine, structural materials and operational controls. All these elements and their interrelationships need to be better understood for efficient and effective wind energy conversion to realize its full potential.

A joint research task underway between NREL and Sandia is called the Long-term Inflow Structural Test program (LIST). Comprehensive measurements on a full scale turbine rotor are planned, in an effort to relate types of atmospheric events to blade fatigue damage. A full season of wind data will be collected at several sites. In a related research task being done by Montana State University, detailed studies are focusing on the fatigue properties of composite blade materials and bonded joints that appear to be failing prematurely in commercial operation. The goal of these efforts is to determine and extend the lifetime of blades and bonded joints.

Avian studies are another important research topic. Ways to reduce or avoid bird fatalities have been the subject of extensive and continuing research. In some regions of California, studies indicate that the level of bird fatalities caused by the turbines is not biologically significant compared to natural conditions. In other areas, namely parts of the Altamont Pass, a significant portion of bird fatalities is attributed to the turbines. A test is being run with 179 golden eagles tagged with radio transmitters and monitored over a three-year period. Data on the eagle population and other biological factors are also being collected.

23.6.2 Turbine Research Program

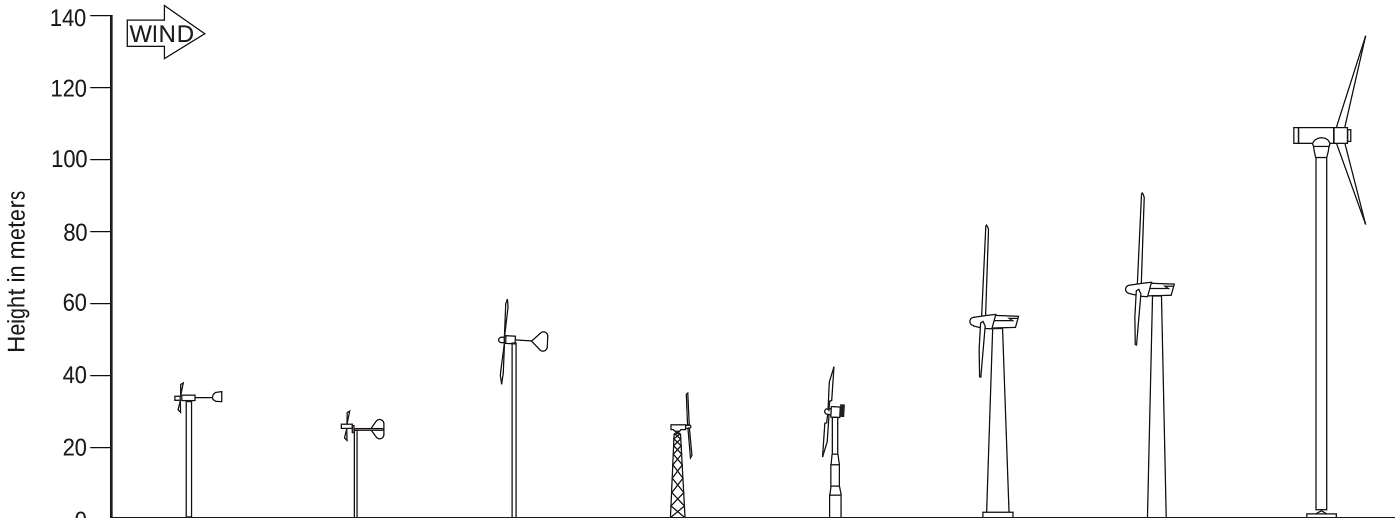
The role of the Turbine Research activity is to provide an opportunity for U.S. industry to apply the technology breakthroughs and design tools from Applied Research, in developing advanced technology wind turbines. This role is implemented through partnerships between DOE National Laboratories and U.S. companies through competitively awarded, cost-shared contracts, typically with 20% to 30% industry cost sharing.

The Turbine Research Program includes development of a variety of turbines in sizes from 6 kW to more than one MW. Next-generation turbine development will employ advanced technology and innovative designs to reach the target levelized costs of electricity of $0.025/kWh (at 6.7 m/s wind sites) around year 2002. These machines will compete directly for bulk electric power markets without the need for subsidies. Subcontracts with industry to develop next-generation turbines include Zond Energy Systems, Incorporated in Tehachapi, California (a subsidiary of Enron Wind Corp.), and The Wind Turbine Company in Belleview, Washington, to design and test a new generation of wind turbines, each about one MW or more. Each company will cost-share 30% of their $20 million contract. Innovative subsystem development activities, currently underway, also support the next-generation path by exploring advanced variable speed generators, blade and rotor manufacturing, and control systems.

Competitively awarded contracts are underway with five companies to develop smaller turbines for both grid-connected and off-grid power generation. The companies selected to develop the new machines are: World Power Technologies, Inc. from Duluth, Minnesota, for a 6-kW turbine; WindLite Company from Mountain View, California, for an 8-kW turbine; Bergey Windpower from Norman, Oklahoma, for a 40-kW turbine and Atlantic Orient from Norwich, Vermont, for improvements to their 50-kW machine.

In Figure 23.6 we see the turbine being developed by Northern Power Systems located in Moretown, Vermont. Nothern Power Systems is developing this 100-kW Polar Turbine under a cooperative program between the National Aeronautics and Space Administration (NASA), the National Science Foundation and DOE. This machine is being designed for the frigid environments of northern Alaska and Antarctica. It includes an innovative low-speed alternator driven directly by the three blade rotor. NASA is considering the design to provide power for life-support systems on a future Mars mission. General characteristics of the advanced turbines under development are shown in Figure 23.7.

Figure 23.6 Northern Power Systems 100-kW Polar Turbine Prototype



		World Power Technology	Bergey Windpower	Atlantic Orient Corporation	Northern Power Systems	Zond Energy Systems	Zond Energy Systems	Wind Turbine Company
Rated power (kW)	8	6	40	50	100	750	1000	1000
Rotor diameter (m)	7	5	16	15	17	50	56	54
Number of blades	3	3	3	3	3	3	3	2
Prototype year	1999	2000	2000	1999	1999	1999	2002	2002
	NEAR TERM						**NEXT GENERATION**	

Figure 23.7 Advanced Utility-Scale Turbines Under Development

23.6.3 Co-operative Research and Testing Program

Work continued under the Turbine Verification Program for the purpose of evaluating new wind turbines and introducing utilities to wind technology. It is the view of DOE and EPRI that if utilities have the opportunity to gain experience in operating small wind plants, they are better able to decide the feasibility of incorporating additional wind generation capability. Under this program, the first two projects were 6-MW installations cost-shared with Central and Southwest Services, a large utility whose service area is centered in the states of Texas and Oklahoma, and with Green Mountain Power, a smaller utility that serves customers in Vermont. Both of these projects are operating well.

Beginning in 1997, DOE and EPRI began a new phase of the Turbine Verification Program under the concept known as Distributed Wind Power Generation. This effort is aimed at utilities or independent power producers interested in building smaller, dispersed wind generation plants connected directly to a distribution line. By the close of 1998, two of those projects had gone on line: the Iowa Distributed Wind Generation Project, a 2.25-MW project with a consortium of small utilities, and a 1.5-MW project with the Nebraska Public Power District in the north-central part of that state. Three additional projects are under development with utilities in the states of Texas, New York, and Oklahoma.

In addition to the cost-shared distributed power projects, the Turbine Verification Program has also entered into agreements with three other utilities. Under these Associate Projects, DOE and EPRI do not provide any direct funding toward the cost of turbines or other major equipment. Instead, funds are primarily limited to support for purchase of System Control And Data Acquisition (SCADA) systems and for technical assistance to the utilities. In return, DOE and EPRI are able to gain information on the performance of additional wind power projects and new turbine types being employed by those projects. At the close of 1998, two Associate Projects were in place with the Wisconsin Public Service Company and the Kotzebue Electric Association in Alaska. A third project in Big Spring, Texas, is being developed by the York Research Corporation, which will sell the wind plant's output to Texas Utilities Electric under a power-purchase agreement.

International standards and certification testing capabilities are areas of increasing emphasis. At the National Wind Technology Center efforts are continuing to provide a full range of certification test capabilities . In August 1998, the Center's procedures for turbine power performance and noise testing, successfully passed an audit by the American Association for Laboratory Accreditation under International Standards Organization (ISO) Guide 25. Testing of commercial turbines has already been completed by the NWTC, and the results have been used by several turbine manufacturers to obtain certifications needed for some overseas markets. Development of harmonized International standards and recommended practices is continuing in work with U.S. industry and international organizations, including the International Electrotechnical Commission and the International Energy Agency.

23.6.4 International Programs

The DOE Wind Program provides technical assistance to governments and utilities in countries planning wind power projects in Central and South America, Asia, Africa and elsewhere. An example is a bilateral agreement with the State Power Corporation of China (formerly Ministry of Electric Power) that allows the exchange of scientists and assistance in planning large scale grid-connected and village power wind projects. Under that Agreement, a pilot project involving the installation of several 10-kW turbines on an isolated island community is planned for 1999.

Other international projects are funded in part by DOE, the United States Environmental Protection Agency, and the Agency for International Development. These activities include assessing opportunities for use of renewables in developing countries, supporting wind / photovoltaic hybrid pilot project tests, feasibility studies for project financing, and supporting renewable energy education efforts. Small turbines have been installed in village power pilot projects in Brazil, Chile, Indonesia, Mexico, Philippines, and Russia. Large-scale wind plant projects in developing countries are supported through technical assistance to the countries and to the regional and multilateral banks.

The 42nd Executive Committee meeting in Copenhagen, Denmark, on September 8–10, 1998.

APPENDIX A

APPENDIX B

IEA R&D EXECUTIVE COMMITTEE 1998
M = Member   A = Alternate Member

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IEA WIND ENERGY ANNUAL REPORT 1998

Wind energy was the world's fastest-growing renewable energy source for the fourth straight year in 1998, with an additional 2,100 MW installed. By April, 1999, worldwide wind energy installed capacity will reach 10,000 megawatts (MW), enough to supply two times the yearly electricity consumption of a city like Madrid, Spain (20 Terawatt hours of energy delivered). Worldwide growth in wind energy is driven by a number of factors including supportive government policies and improved technology.

To conduct joint research projects and exchange information, parties from 17 countries and the European Commission collaborate in wind energy research and development under the auspices of the International Energy Agency. This Implementing Agreement for Co-operation in the Research and Development of Wind Turbine Systems (IEA R&D Wind) encourages and supports the technological development and global deployment of wind energy technology. This report reviews the progress of the joint projects conducted during 1998 and highlights the national wind energy activities in the member countries of IEA R&D Wind.

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